J Anesth (2015) 29:360–366
DOI 10.1007/s00540-014-1941-4

ORIGINAL ARTICLE

The effect of preeclampsia on the skin to subarachnoid distance in spinal anesthesia

B. Basaran · A. Basaran · B. Kozanhan · S. Ozmen · M. Basaran

Received: 8 July 2014 / Accepted: 19 October 2014 / Published online: 7 November 2014

Abstract
Background Preeclampsia is characterized by increased extracellular fluid which manifests as generalized edema due to endothelial injury and subsequent capillary leak. Therefore, preeclampsia may lead to increased skin to subarachnoid distance (SSD) which may influence daily clinical practice in this particular gravid population.
Methods Age- and height-matched gravidas with and without preeclampsia were enrolled prospectively at an allocation ratio of 1:4. Spinal anesthesia (SA) was performed in a sitting position by a mid-line approach at the L3–L4 interspace using a 25-gauge Quincke spinal needle. An internal pilot study was performed to determine the sample size. When the protocol violations were excluded, 146 gravidas were included in the study (25 preeclamptics and 121 normotensive controls) for final analysis.
Results On average, SSD was 0.89 cm greater in preeclamptics compared to normotensive controls. Mean values of the SSD in preeclamptic and normotensive control group patients at the L3–L4 interspace were 6.187 ± 0.967 and 5.301 ± 0.834 cm, respectively. SSD was significantly correlated with body weight and body mass index (BMI). The regression formula for the estimation of SSD in preeclamptic gravidas with BMI during SA was SSD = 3.696 + 0.075×BMI. The regression formula for the estimation of SSD in the normotensive control group with BMI during SA was SSD = 3.144 + 0.067×BMI − 0.0001×BMI×BMI.
Conclusion Knowing that the SSD is increased in preeclamptics compared to normotensive gravidas may be of value in terms of selecting needle, and providing safe and comfortable anesthesia.

Keywords Spinal anesthesia · Preeclampsia · Skin to subarachnoid distance

Abbreviations

SSD	Skin to subarachnoid distance
SA	Spinal anesthesia
SED	Skin to epidural distance
ACOG	American College of Obstetricians and Gynecologists
ASA	American Society of Anesthesiologists
ASA PS	American Society of Anesthesiologists Physical Status

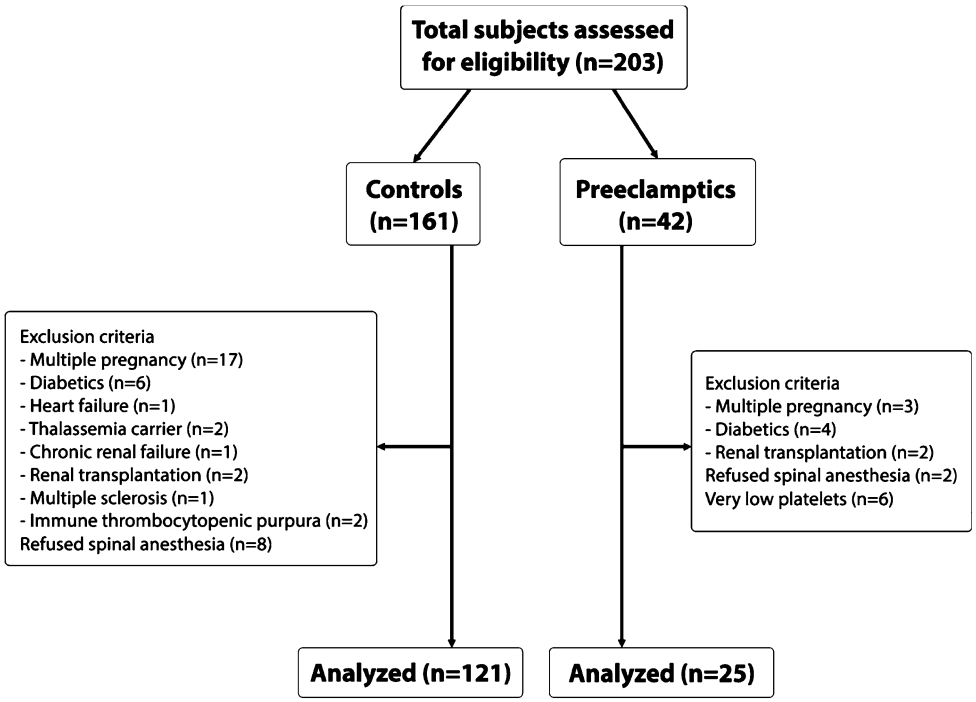
Introduction

Preeclampsia is characterized by increased extracellular fluid which manifests as generalized edema. The mechanism of pathological fluid retention is thought to be due to endothelial injury and subsequent capillary leak [1]. The degree of glomerular capillary leak causing proteinuria, which reduces plasma oncotic pressure, further aggravates the clinical picture. Preeclampsia is a pregnancy-specific syndrome that can affect virtually every body part or organ system, as does the edema it causes [1]. Although not prominent like facial, pretibial, and abdominal edema, lumbosacral edema can be observed in patients with preeclampsia. The incidence and severity of lumbosacral edema

B. Basaran (✉) · B. Kozanhan · S. Ozmen
Anesthesiology Department, Konya Training and Research Hospital, Kılıçarslan Mah, Nurdağ Sk., Sinanoba Sitesi, B-blok No:19, Selçuklu, 42080 Konya, Turkey
e-mail: betulbasaran1@yahoo.com

A. Basaran · M. Basaran
Obstetrics and Gynecology Department, Konya Training and Research Hospital, Konya, Turkey

Fig. 1 Study flowchart



in preeclamptic gravidas, and the resulting effect on the skin to subarachnoid distance (SSD) and performance of spinal anesthesia (SA) has not been thoroughly investigated in the English literature. Although an increase in SSD is anticipated in preeclamptics, to what extent preeclampsia affects SSD has not been investigated. Distance from skin to epidural space and SSD, and their reference ranges have been published previously [2, 3]; however, studies in the obstetric population are limited and based on healthy gravidas. Hence, the purpose of this study is to determine the difference in SSD between preeclamptic and normotensive pregnant patients.

Methods

In order to evaluate the SSD, age-matched and height-matched subjects were enrolled in a prospective cohort study (Fig. 1). Due to the edematous state and excessive weight gain associated with preeclampsia, patients were not matched according to body weight. Consecutive severe preeclamptic and normotensive gravidas scheduled for cesarean section were included. Because the incidence of severe preeclampsia is approximately 1 % [4], we planned an allocation ratio of 1:4. Severe preeclamptics were chosen because of the frequent requirement of cesarean section which is approximately 75–90 % [5]. Patient characteristics including age, height, body weight, body mass index (BMI), and gestational age and laboratory values were recorded preoperatively. As the effect of preeclampsia on SSD has not been previously evaluated in the English literature, we performed an internal pilot study to determine the sample size [6].

Internal pilot study

Sample size was calculated from the estimated parameters ([standard_deviation1-0.962, standard_deviation2-1.224], difference of means [0.7459]) obtained from the pilot study. The planned allocation ratio was 1:4 and 51 patients were included in the pilot study. To calculate the sample size we used PiFace version 1.76 [7]. The calculated sample sizes with an allocation ratio of 1:4, alpha 0.05 and power of 90 % were 25 for preeclampsia and 100 for the normotensive control group. The number of subjects was increased to account for protocol violation.

Exclusion criteria

Exclusion criteria included multi-fetal gestation, previous diagnosis of renal failure, heart failure, and either gestational or type I/II diabetes mellitus, allergy to local anesthetics, neurologic and hematologic diseases excluding the manifestations of preeclampsia, and gravidas that refused SA.

Diagnosis and determination of severe features preeclampsia

Recently, the American College of Obstetricians and Gynecologists (ACOG) updated their guidelines for the management of hypertensive disorders in pregnancy.

Table 1 Criteria for severe features of preeclampsia (any of these findings)

Systolic blood pressure ≥160 mmHg, or diastolic pressure ≥110 mmHg on two occasions at least 4 h apart while the patient is on bed rest (unless antihypertensive therapy is initiated before this time)
Thrombocytopenia (platelet count <100,000/μl)
Impaired liver function (twice the normal concentration), severe right upper quadrant pain or epigastric pain unresponsive to medication and not accounted for by alternative diagnosis, or both
Progressive renal insufficiency (serum creatinine concentration >1.1 mg/dl or a doubling of the serum creatinine concentration in the absence of other renal disease)
Pulmonary edema
New-onset cerebral or visual disturbances

Diagnostic criteria for preeclampsia and criteria for severe features of preeclampsia were adopted from the ACOG guidelines, of which details can be found elsewhere [8]. New-onset hypertension with proteinuria was used for the diagnosis of preeclampsia. In the absence of proteinuria, new-onset hypertension with any of the following—thrombocytopenia, renal insufficiency, impaired liver function, pulmonary edema, or cerebral or visual disturbances—was used to diagnose preeclampsia [8]. Only severe preeclamptic patients were included in the study. Severe features of preeclampsia were defined according to the criteria provided in Table 1 [8].

Spinal anesthesia and SSD measurement

After arrival in the operating room, continuous monitoring of vital signs (ECG, noninvasive blood pressure and pulse oximetry) was introduced. Before the spinal injection, 500 ml lactated Ringer's solution was administered by rapid intravenous infusion. The bony landmarks and possible place of L3–L4 was marked using Tuffier's line as a guide. After aseptic preparation of skin, SA was performed in a sitting position by a mid-line approach at the L3–L4 interspace using a 25G × 90 mm Quincke spinal needle that was inserted perpendicular to the skin. There was free flow of clear cerebrospinal fluid as the needle entered the subarachnoid space. Following an intrathecal injection, the spinal needle was grasped between the thumb and index finger during removal from the patient's back. From the point grasped, the SSD was measured using rulers. An attempt to reach the subarachnoid space was accepted as failure if the needle was retracted for patient discomfort, contact with bony structures, or changing the needle angle. The number of attempts was recorded. All SA procedures were performed by anesthetists with over 5 years of experience (BB and BK).

Statistical analysis

Normal distributions of the variables were assessed via Kolmogorov–Smirnov test, Q–Q plots and histograms. Mean ± standard deviation were reported for continuous variables and median and ranges were reported for ordinal and categorical variables. Baseline characteristics were compared using the *t* test for normally distributed continuous variables and Mann–Whitney *U* test for continuous variables without normal distribution and ordinal variables. Categorical variables were compared using chi-squared test with post hoc tests when required. For the detection of associations between variables, correlation analysis with construction of correlation matrix was performed. Significant correlations with large effect sizes according to Cohen's guidelines were used to indicate the presence of factors that may affect SSD. Curve fitting and regression analysis were used for curve estimation and the corresponding equations were obtained. For the indicated equations, residual plots were obtained and controlled for symmetry and linearity; from these equations estimated mean values were calculated according to BMI.

All statistical tests were two-sided with a significance level of 0.05. Analyses were exploratory and did not adjust for multiple testing. Data analysis and management was performed using IBM SPSS 21 (IBM SPSS Statistics for Windows, version 21.0; IBM Corp. Armonk, NY, USA).

Ethics statement

All study documents and procedures were approved by the institutional review board at the University of Selçuk, Konya. All subjects provided written informed consent prior to initiation of study procedures. The study protocol conforms to the ethical guidelines of the 2013 Declaration of Helsinki [9].

Results

A total of 146 gravidas (121 normotensive and 25 preeclamptic patients) were included for statistical analysis (Fig. 1). Patient characteristics are shown in Table 2. Patients with preeclampsia had higher BMI and body weight just before delivery; however, the BMI and body

Table 2 Patient demographics

	Preeclampsia group[a]	Normotensive group[a]	*p*
Age	28.52 ± 6.015	28.75 ± 5.707	0.855
ASA	3 (1)	1 (2)	0.001
Gravidity	2 (5)	3 (5)	0.355
Living children	1 (0–5)	1 (0–5)	0.176
Height	160.96 ± 4.95	160.47 ± 6.97	0.96
Infant birth weight (g)	2,301 ± 812.372	3,250.86 ± 523.352	0.001
Gestational age (weeks)	34.65 ± 3.2	38.38 ± 1.496	0.001
Number of attempts for needle insertion	1 (3)	1 (2)	0.213
SSD (cm)	6.187 ± 0.967	5.301 ± 0.834	0.001
Initial mean arterial pressure	129.61 ± 20.268	99.65 ± 12.37	0.001
Initial pulse rate	93.87 ± 15.337	100.47 ± 16.380	0.076
Initial oxygen saturation	98.87 ± 1.517	98 ± 1.461	0.851
Body weight before pregnancy (kg)	72.17 ± 15.622	66.26 ± 14.038	0.086
Body weight before delivery (kg)	85.92 ± 13.279	78.28 ± 14.902	0.019
BMI before pregnancy	27.825 ± 6.529	25.778 ± 5.524	0.104
BMI before delivery	33.161 ± 6.747	30.439 ± 5.861	0.036
Absolute weight gain during pregnancy (kg)	13.96 ± 8.638	12.02 ± 5.561	0.290
Corrected weight gain during pregnancy (g)	13,498 ± 9,587	9,127 ± 5,650	0.036

ASA American Society of Anesthesiologists, *SSD* skin to subarachnoid distance

[a] Either mean ± standard deviation or median (ranges) were reported in this table

weight before pregnancy were not statistically different between groups. Gravidas with preeclampsia were also delivered 3.73 weeks earlier than the control group. Patients with preeclampsia had significantly lower birth weight; however, the absolute weight gain during pregnancy between groups was not significantly different. To control for the effect of gestational age and birth weight we used the formula ([weight gain − birth weight]/[gestational age/40]). After correction, the weight gain was significantly higher in preeclamptic gravidas ($p = 0.036$). Although the patients with preeclampsia were delivered earlier with a lower birth weight, they had gained more weight than the controls which is probably due to increased extracellular fluid and generalized edema. As expected, the American Society of Anesthesiologists (ASA) physical status (PS) scores and mean arterial pressures during SA were higher in the preeclamptic group.

Mean values of the SSD in preeclamptic and normotensive control group patients at the L3–L4 interspace were 6.187 ± 0.967 cm and 5.301 ± 0.834 cm, respectively. SSD was significantly greater in preeclamptics compared to normotensive controls. In the constructed correlation matrix, SSD was significantly correlated with grouping variable, gestational age, ASA PS score, weight before pregnancy, weight before delivery, BMI before pregnancy, BMI before delivery, infant birth weight, number of attempts, and initial mean arterial pressure. When the two groups were analyzed separately gestational age, ASA score, infant birth weight, number of attempts and mean arterial pressure lost their significance. The correlations between SSD and BMI (Spearmans rho statistic $[r_s] = 0.433$, $p = 0.001$ normotensive control; $[r_s] = 0.412$, $p = 0.041$ preeclamptic) and body weight ($[r_s] = 0.430$, $p = 0.001$ normotensive; $[r_s] = 0.410$, $p = 0.042$) retained their significance in both groups. Curve fitting was used to obtain regression equations according to BMI before delivery. The regression equation for the estimation of SSD in preeclamptic gravidas with BMI before delivery was SSD = 3.696 + 0.075×BMI (R-squared = 0.199; $p = 0.025$). The regression equation for the estimation of SSD in normotensive gravidas with BMI before delivery was SSD = 3.144 + 0.067×BMI − 0.0001×BMI×BMI (R-squared = 0.283; $p = 0.001$). Estimated regression formulas for SSD superimposed onto a scatter plot according to BMI before delivery are shown in Fig. 2.

Discussion

Measurement of the skin to epidural distance (SED) in the obstetric population had been the subject of several studies in the English literature and various mathematic models have been proposed to estimate the measurement [10–13]. However, studies determining SSD in the obstetric population are few and have not evaluated differences, if any. Moreover, they were based on healthy pregnant subjects [2, 14]. To the best of our knowledge, this is the first study to evaluate the effect of preeclampsia on SSD. Our study hypothesis was that there would be a significant difference in SSD between preeclamptic and normotensive controls due to underlying disease pathophysiology. In accordance with our hypothesis, SSD was larger by an average of 0.89 cm in preeclamptic patients. As in previous studies,

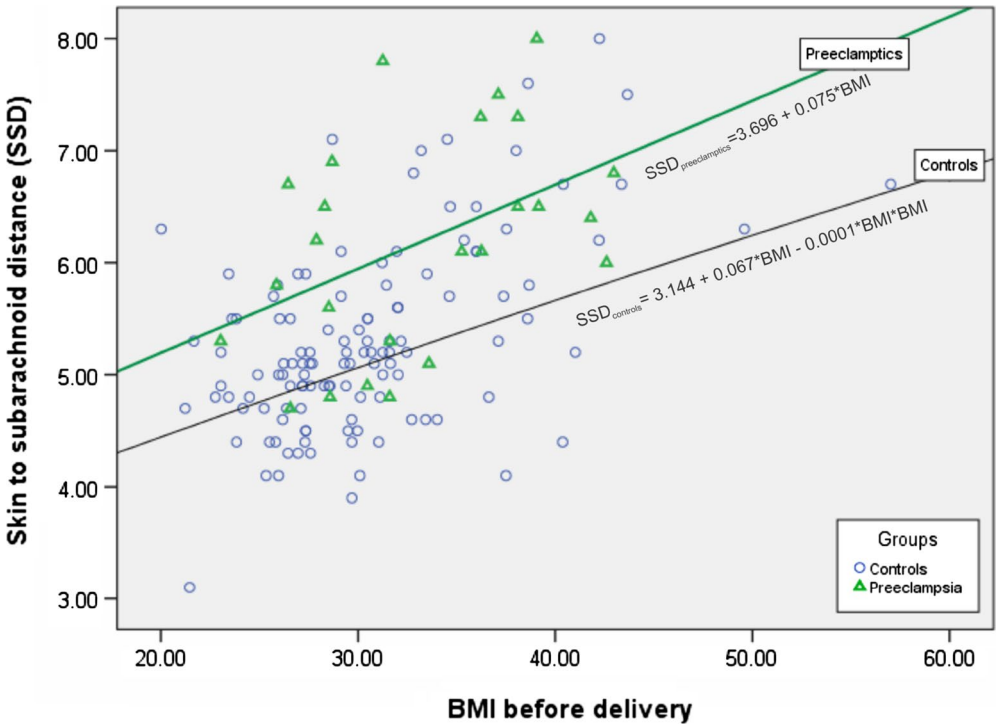


Fig. 2 Scatter plot with superimposed estimated regression equations and lines according to groups

BMI significantly influenced the SSD as well as preeclampsia; however, with increasing BMI, the difference in SSD between preeclamptics and normotensive controls also increased (Fig. 2). In 1990, Meiklejohn et al. reported SED in gravidas without preeclampsia receiving epidural anesthesia during labor [12]. They compared patients who were noted by the anesthetist to have clinically significant edema with patients without and found a significantly deeper distance in patients who seemed to be edematous (5.44 vs 4.69 cm) [12]. Besides preeclampsia, pregnancy itself is characterized by increased extracellular fluid which may lead to increased SSD; however, without doubt preeclampsia further expands the SSD.

Preeclampsia affects 5–7 % of pregnancies and is a significant cause of maternal and neonatal morbidity and mortality [15]. As emphasized by practice guidelines from the ASA and the ACOG, neuraxial anesthetic techniques, when feasible, are strongly preferred to general anesthesia for preeclamptic parturients. Formerly, concerns of SA for patients with preeclampsia were precipitous hypotension and its effect on preexisting uteroplacental hypoperfusion, risk of inducing hypertension and pulmonary edema with subsequent efforts to correct hypotension [16]. These factors which prevented the widespread use of SA in severe preeclamptics are probably one of the reasons which prevented the study of SSD in preeclamptics. However, further studies showed that parturients with severe preeclampsia experience less frequent and less severe hypotension, and smaller ephedrine requirement than healthy parturients [16, 17]. The explanation given suggested that preeclampsia is characterized by vasospasm with increased sensitivity to vasopressors and preeclamptics tend to have smaller fetuses which could result in less aortocaval compression [17]. Therefore, SA has become a reasonable option in severe preeclampsia when emergent cesarean delivery is indicated. Moreover, generalized edema in preeclampsia can be a major concern in anesthetic management resulting in narrower upper airway, exacerbated hypertension, failed intubation and aspiration [18] or pulmonary edema [19]. Accordingly, maternal mortality statistics identify general anesthesia as a greater risk to paturients than neuraxial techniques [20, 21]. In the present study, we demonstrated that edema in subcutaneous tissue in preeclamptics changes the SSD and gives rise to the need to establish a relationship between physical parameters and SSD.

SA offers quicker onset of anesthesia than epidural or combined spinal epidural anesthesia, which is a critical advantage in emergency situations. When faced with a preeclamptic patient who needs urgent cesarean section, there needs to be an opinion about SSD in order to prevent failure to reach the subarachnoid space. In this context, the selection of spinal needle length becomes a priority. When spinal needles are used with an introducer, the effective length of the needle is shortened by 12–22 mm depending on the

needle pack used [22, 23]. Although the introducer needle is helpful to reduce deflection (which is particularly useful in obese patients), the effect of the introducer combined with the effect of preeclampsia on SSD probably increases the chance of inadequate block. The type of needle set and technique that can reach the dura should be chosen according to the estimated SSD of the preeclamptic patient. On the other hand, if an epidural or combined spinal/epidural is selected as an anesthetic management technique during cesarean section, a more precise estimate of the SSD could help to reduce the risk of inadvertent dural puncture [11], or prevent failure to reach the subarachnoid space [24, 25]. Taking everything into consideration, we also analyzed the number of attempts for SA and whether the presence of preeclampsia increased the number of attempts for SA; however, there was no significant difference between the two groups. Although preeclampsia significantly increases SSD, this did not translate into an increased number of attempts in our study.

In the present study, SSD for the whole cohort was 5.45 ± 0.92 cm (3.1–8). Bassiakou et al. reported that the median SSD at the same level in the lateral decubitus position was 6.5 ± 1.2 cm (4.6–10) [2]. Recently, Prakash et al. reported a mean SSD value of 4 cm [14], which is considerably less than previous studies. The disparity in these values can partly be explained by differences in the methods of measurement, the positioning of the parturient, and the type and heterogeneity of the particular population. However, both studies reported that weight and BMI significantly affected SSD, which was in agreement with our study.

Ultrasonography was used to determine the subarachnoid space in previous studies [26, 27]. However, during the course of pregnancy, weight gain and edema cause a decrease in the visibility of the ligamentum flavum [28]. Preeclampsia-related edema may possibly further increase the difficulty in visualization of the ligamentum flavum. Although these factors create further challenges, ultrasound-guided studies may be performed to construct physical parameters as significant predictors of the SSD in preeclamptic parturients.

In conclusion, when conducting a cesarean delivery in preeclamptic patients via regional techniques, knowledge of increased SSD compared to normotensive gravidas may be of some value in selecting appropriate needle/needle set, and in terms of safety and success.

Acknowledgments Conflict of interest The authors declare that there are no conflicts of interest.

References

1. Cunningham FG, Leveno KJ, Bloom SL, Spong CY, Dashe JS, Hoffman BL, Casey BM, Sheffield JS, editors. Hypertensive disorders. In: Williams obstetrics. McGraw-Hill Education; 2014. p. 2511–694.
2. Bassiakou E, Valsamidis D, Loukeri A, Karathanos A. The distance from the skin to the epidural and subarachnoid spaces in parturients scheduled for caesarean section. Minerva Anestesiol. 2011; 77(2):154–159. pii: R02105827.
3. Shiroyama K, Izumi H, Kubo T, Nakamura R. Distance from the skin to the epidural space at the first lumbar interspace in a Japanese obstetric population. Hiroshima J Med Sci. 2003;52(2):27–9.
4. Zhang J, Meikle S, Trumble A. Severe maternal morbidity associated with hypertensive disorders in pregnancy in the United States. Hypertens Pregnancy. 2003;22(2):203–12. doi:10.1081/PRG-120021066.
5. Zhang Y, Li W, Xiao J, Chen S. The complication and mode of delivery in Chinese women with severe preeclampsia: a retrospective study. Hypertens Pregnancy. 2014;33(3):283–90. doi:10.3109/10641955.2013.874440.
6. Lenth RV. Some practical guidelines for effective sample size determination. Am Stat. 2001;55(3):187–93. doi:10.1198/000313001317098149.
7. Lenth RV. Java applets for power and sample size (computer software). 2006 http://www.stat.uiowa.edu/~rlenth/Power. Accessed 6 12 2014.
8. American College of Obstetricians Gynecologists; Task Force on Hypertension in Pregnancy. Hypertension in pregnancy. Obstet Gynecol. 2013;122(5):1122–31. doi:10.1097/01.AOG.0000437382.03963.88.
9. World Medical Association. World medical association declaration of Helsinki: ethical principles for medical research involving human subjects. J Am Med Assoc. 2013;310(20):2191–4. doi:10.1001/jama.2013.281053.
10. Chen KP, Poon YY, Wong CH. The depth to the epidural space. Ma Zui Xue Za Zhi. 1989;27(4):353–6.
11. Hoffmann VL, Vercauteren MP, Buczkowski PW, Vanspringel GL. A new combined spinal-epidural apparatus: measurement of the distance to the epidural and subarachnoid spaces. Anaesthesia. 1997;52(4):350–5.
12. Meiklejohn BH. Distance from skin to the lumbar epidural space in an obstetric population. Reg Anesth. 1990;15(3):134–6.
13. Preusser A, Nolte H. An attempt at a mathematical prediction of the depth of insertion of the needle in peridural anesthesia. Anaesthesiol Reanim. 1991;16(2):108–16.
14. Prakash S, Mullick P, Chopra P, Kumar S, Singh R, Gogia AR. A prospective observational study of skin to subarachnoid space depth in the Indian population. Indian J Anaesth. 2014;58:165–70. doi:10.4103/0019-5049.130819.
15. Steegers EA, von Dadelszen P, Duvekot JJ, Pijnenborg R. Pre-eclampsia. Lancet. 2010;376(9741):631–44. doi:10.1016/S0140-6736(10)60279-6.
16. Henke VG, Bateman BT, Leffert LR. Focused review: spinal anesthesia in severe preeclampsia. Anesth Analg. 2013;117(3):686–93. doi:10.1213/ANE.0b013e31829eeef5.
17. Aya AG, Vialles N, Tanoubi I, Mangin R, Ferrer JM, Robert C, Ripart J, de La Coussaye JE. Spinal anesthesia-induced hypotension: a risk comparison between patients with severe preeclampsia and healthy women undergoing preterm cesarean delivery. Anesth Analg. 2005;101(3):869–75. doi:10.1213/01.ANE.0000175229.98493.2B.
18. Izci B, Riha RL, Martin SE, Vennelle M, Liston WA, Dundas KC, Calder AA, Douglas NJ. The upper airway in pregnancy and pre-eclampsia. Am J Respir Crit Care Med. 2003;167(2):137–40. doi:10.1164/rccm.200206-590OC.
19. Zieleskiewicz L, Contargyris C, Brun C, Touret M, Vellin A, Antonini F, Muller L, Bretelle F, Martin C, Leone M. Lung ultrasound predicts interstitial syndrome and hemodynamic

profile in parturients with severe preeclampsia. Anesthesiology. 2014;120(4):906–14. doi:10.1097/ALN.0000000000000102.
20. Mhyre JM, Riesner MN, Polley LS, Naughton NN. A series of anesthesia-related maternal deaths in Michigan, 1985–2003. Anesthesiology. 2007;106(6):1096–104. doi:10.1097/01.anes.0000267592.34626.6b.
21. Hawkins JL, Koonin LM, Palmer SK, Gibbs CP. Anesthesia-related deaths during obstetric delivery in the United States, 1979–1990. Anesthesiology. 1997;86(2):277–84.
22. Corfe J. Length of spinal needles. Anaesthesia. 2008;63(4):444–5. doi:10.1111/j.1365-2044.2008.05512.x.
23. Ahn WS, Bahk JH, Lim YJ, Kim YC. The effect of introducer gauge, design and bevel direction on the deflection of spinal needles. Anaesthesia. 2002; 57(10):1007–1011. pii: 2657.
24. Joshi GP, McCarroll SM. Evaluation of combined spinal-epidural anesthesia using two different techniques. Reg Anesth. 1994;19(3):169–74.
25. Lyons G, Macdonald R, Mikl B. Combined epidural/spinal anaesthesia for caesarean section. Through the needle or in separate spaces? Anaesthesia. 1992;47(3):199–201.
26. Gnaho A, Nguyen V, Villevielle T, Frota M, Marret E, Gentili ME. Assessing the depth of the subarachnoid space by ultrasound. Rev Bras Anestesiol. 2012;62(4):520–30. doi:10.1016/S0034-7094(12)70150-2.
27. Shenkman Z, Rathaus V, Jedeikin R, Konen O, Hoppenstein D, Snyder M, Freud E. The distance from the skin to the subarachnoid space can be predicted in premature and former-premature infants. Can J Anaesth. 2004;51(2):160–2. doi:10.1007/BF03018776.
28. Grau T, Leipold RW, Horter J, Conradi R, Martin E, Motsch J. The lumbar epidural space in pregnancy: visualization by ultrasonography. Br J Anaesth. 2001;86(6):798–804.